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SOLAR

A DIVISION OF INTERNATIONAL HARVESTER COMPANY

SOLAR | 2200 PACIFIC HIGHWAY, SAN DIEGO, CALIFORNIA

ENGINEERING REPORT

GAS TURBINE REGENERATORS
FOR
MARINE ENVIRONMENT

Third Quarterly Progress Report

January-March 1966

REPORT ER 1681-2 ISSUED 15 April 1966

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* U.S. Patent 2,856,281

ABSTRACT

During this report period, 16 parent material-braze alloy combinations have been exposed to testing in the corrosion test rig. Results of this preliminary evaluation are discussed in terms of microstructural attack. Three core modules, fabricated with various passage shapes, are described and projected testing is outlined.

I. INTRODUCTION

Under Bureau of Ships sponsorship, Solar, a Division of International Harvester, has undertaken this program related to gas turbine regenerators for marine environment. This program is divided into two main areas of investigation -- materials evaluation and development of fabrication and forming techniques.

The eighteen month program was initiated on 1 July 1965 under the direction of Mr. Charles P. Howard, project manager of Code 645, Bureau of Ships. E. C. Thorsrud, Solar Senior Research Engineer, has been appointed principal investigator. This document constitutes the third quarterly progress report submitted under the program, covering the activities in January through March 1966.

II. OBJECTIVES OF THE REPORTING PERIOD

1. Initiation of corrosion rig testing and completion of approximately 1000 hours of specimen exposure.
2. Further investigation of forming techniques.
3. Start fabrication of sample modules for evaluation of braze joining.

III. TECHNICAL DISCUSSION

3.1 MATERIALS EVALUATION

Approximately 1000 hours of testing have been completed in the corrosion test rig under the following summarized test parameters:

Unit Test Time: 200 hours of 24 hour test cycles

Test Cycle Conditions: 16 hours exhaust gas exposure
8 hours quiescent salt air exposure

Exhaust Gas Conditions: Combustor discharge at 1000° F with ASTM D-665-60 salt water injected downstream at the rate of 15 parts per million parts of inlet air. Gas at coupon, flows at rate of 50 fps.

Quiescent Salt Air Exposure: Immediately following exhaust gas exposure, burner is shut off and salt spray maintained for one hour. Spray is then discontinued and rig allowed to soak for remainder of cycle.

Materials Tested: Six specimens of each parent material/braze alloy combination per test.

Test No.	Parent Material	Braze Alloy
1	Type 347	Solar IX1*
	Type 347	Coast Metals 53
	Type 430	Coast Metals 53
	Type 430	GE 8201 B
2	Hastelloy C	Coast Metals 53
	Hastelloy C	GE 8201 B
	Type 430	Nicrobraze 50
	Inconel 600	Nicrobraze 50
3	Inconel 600	Coast Metals 53
	Type 347	GE 8201 B
	Type 347	Nicrobraze 50
	Hastelloy C	Nicrobraze 50
4	Inconel 600	Solar IX1*
	Type 430	Solar IX1*
	Hastelloy C	Solar IX1*
	Inconel 600	GE 8201 B

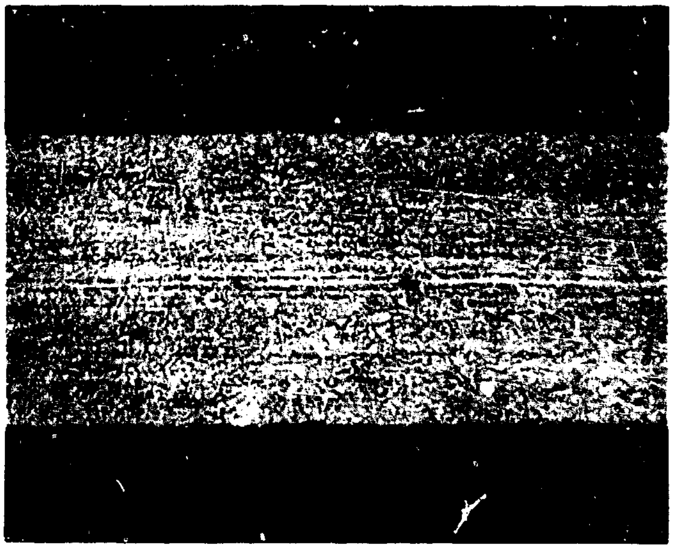
Photomicrographs of the parent material foils (10 mil) in the "as received" condition (Figures 1-3) are used as a basis of comparison with post-test photomicrographs (Figures 4-7). The poor braze flow depicted in Figure 4 was local in extent and not typical of the overall joint. It is of interest in demonstrating the reduced joint efficiency possible in visually acceptable braze joints. The break noted in the tang of Figure 5 was accidentally induced in preparing the specimen and is not related to the corrosive exposure.

Generally, there is no significant attack observed on these typical photomicrographs or on any of the other specimens examined. The incipient intergranular attack on the Inconel 600 (grain boundary oxidation) and Type 430 (pitting) are not adequate bases for materials ranking.

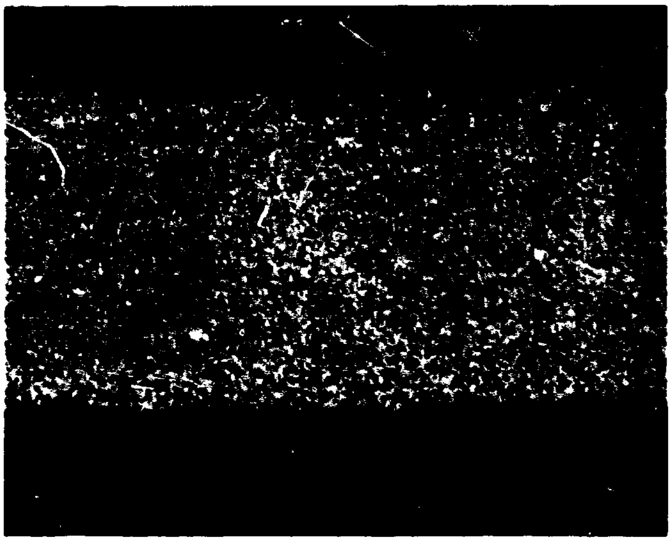
The coupons were also tested for ductility by folding the braze joint over 180 degrees. (Figures 8-10) No failures were observed on the tensile surface confirming the metallurgical evidence of relative freedom from attack.

Investigation of the rig revealed that although appreciable salt deposits were accumulated on the test specimens during testing, they quickly dried after salt spray was discontinued. The rig has been modified with salt water aspirators to maintain a wet salt steam environment during the final four hours of the quiescent phase.

*U.S. Patent 2,856,281

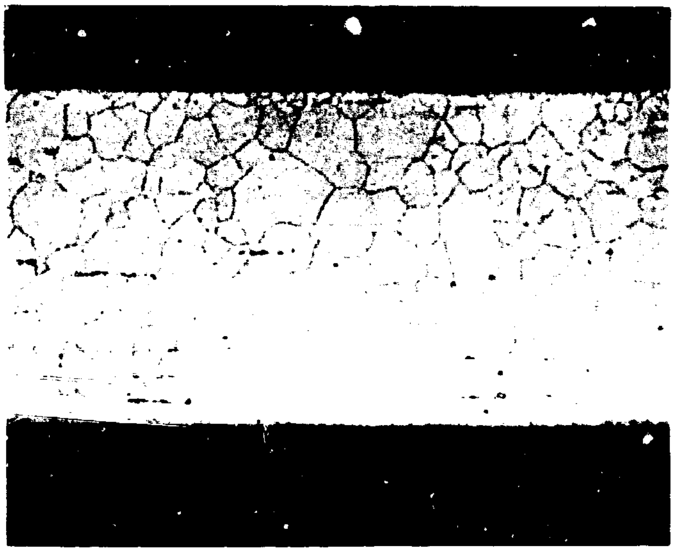


Type 437 - 150 x



Type 430 - 150 x

FIGURE 1 - FOIL MATERIAL IN "AS RECEIVED CONDITION"

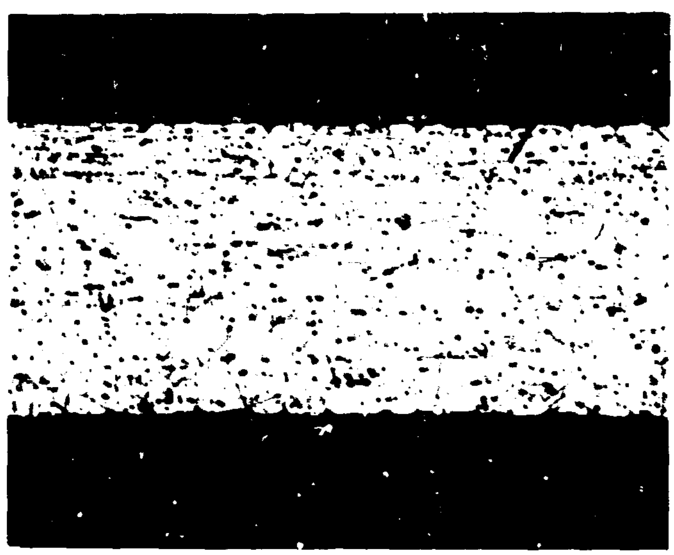


Inconel 600 - 150 x

Incoloy 800 - 150 x

FIGURE 2 - FOIL MATERIAL IN "AS RECEIVED CONDITION"

Hastelloy C - 150 x

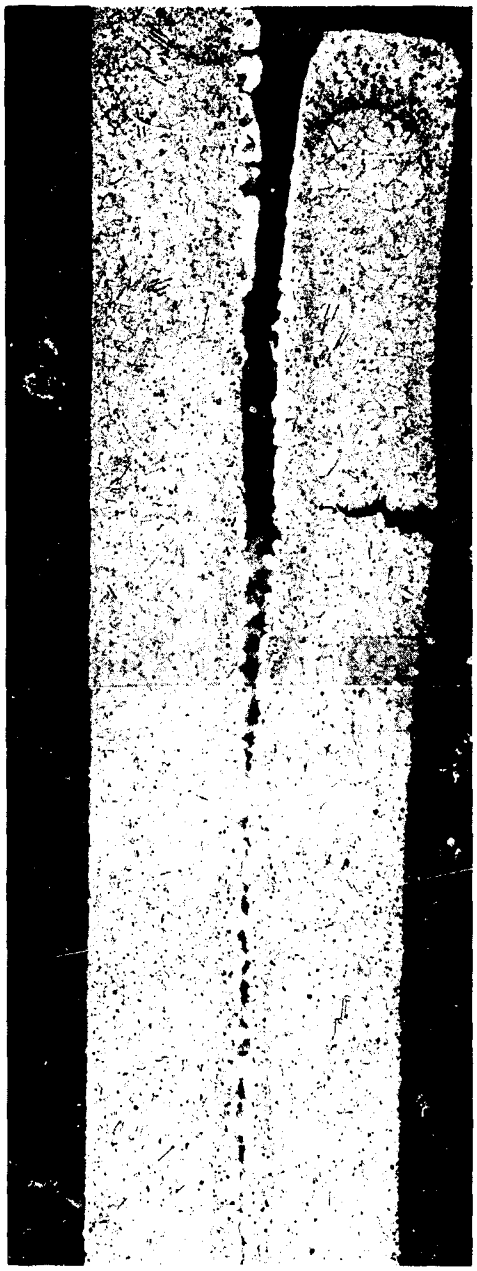


Hastelloy F - 150 x

FIGURE 3 - FOIL MATERIAL IN "AS RECEIVED CONDITION"

Post-test Section

FIGURE 4 - TYPE 430/NICROBRAZE 50 - 75 x

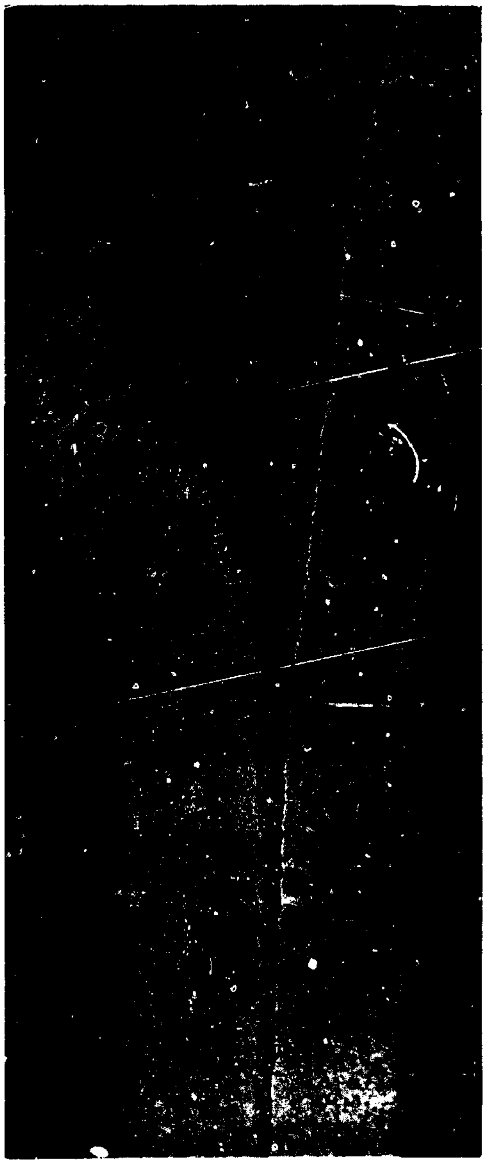


Post-test Section

FIGURE 5 - HASTELLOY C/NICROBRAZE 50 - 77 x

Post-test Section

FIGURE 6 - INCONEL 600/COAST METALS 53 - 77 x



Post-test Section

FIGURE 7 - TYPE 430/GE 8201 B - 77 x

3.2 FORMING AND JOINING TECHNIQUES

In the last report period, it was established that corrugations may be formed with extremely small nose radii (triangular shaped passage) or quarter-pitch radii ("U" shaped passage). Die life would be limited in forming small nose radii but might be justified if improved heat transfer characteristics were obtained. Two unbonded core modules (Figures 11 and 12) were fabricated with widely different passage shapes and are scheduled for testing at the U.S. Naval Postgraduate School at Monterey, California. Another question raised on the interaction of forming/joining and performance is the influence of braze fillet size. Since the unbonded core module already represents the one extreme of zero fillet size, a third module was brazed with the largest attainable fillet size. This third unit is also scheduled for thermal transient performance evaluation. (Figure 13)

Conventional punch and die tooling for a six inch cube cross-flow heat exchanger module has been completed. Some preliminary investigations are underway to determine variables influencing height and flatness control. The forming system used must accomplish the dimensional control required for good braze practice without creating high residual stresses. Braze alloy is particularly aggressive on stressed foils and will easily erode through such areas.

Photomicrographs of Figures 14-16 are of a node of one convolution formed from 6" width core material, sectioned at both outside edges and at the center. The purpose was to study the microstructure to determine if the forming operation resulted in a high stress area at the node.

IV. EXPECTED PROGRESS DURING THE NEXT REPORTING PERIOD

1. Continuation of corrosion rig testing with more aggressive environment.

2. Fabricate modules in six inch cubes for evaluation of braze stack-up control.

3. Formulate program for evaluation of fabrication problems with large modules.

FIGURE 8 - DUCTILITY TEST - TYPE 347/SOLAR IX1* - 35 x

*U.S. Patent 2,856,281

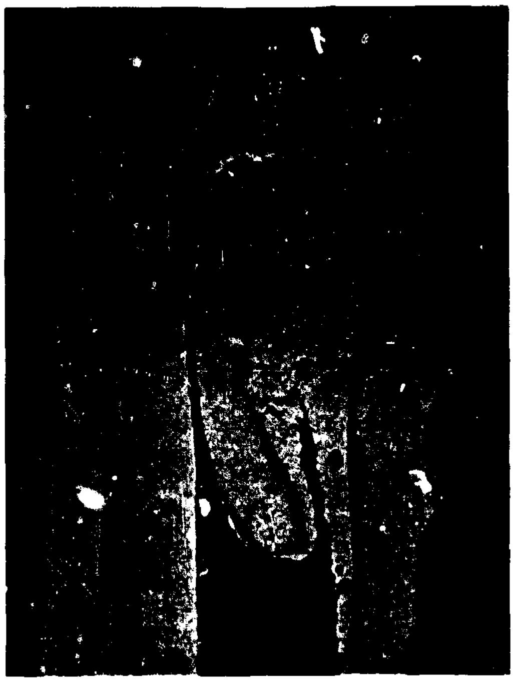


FIGURE 9 - TYPE 430/GE 8201 B - 35 x

FIGURE 10 - TYPE 430/NICROBRAZE 50 - 35 x

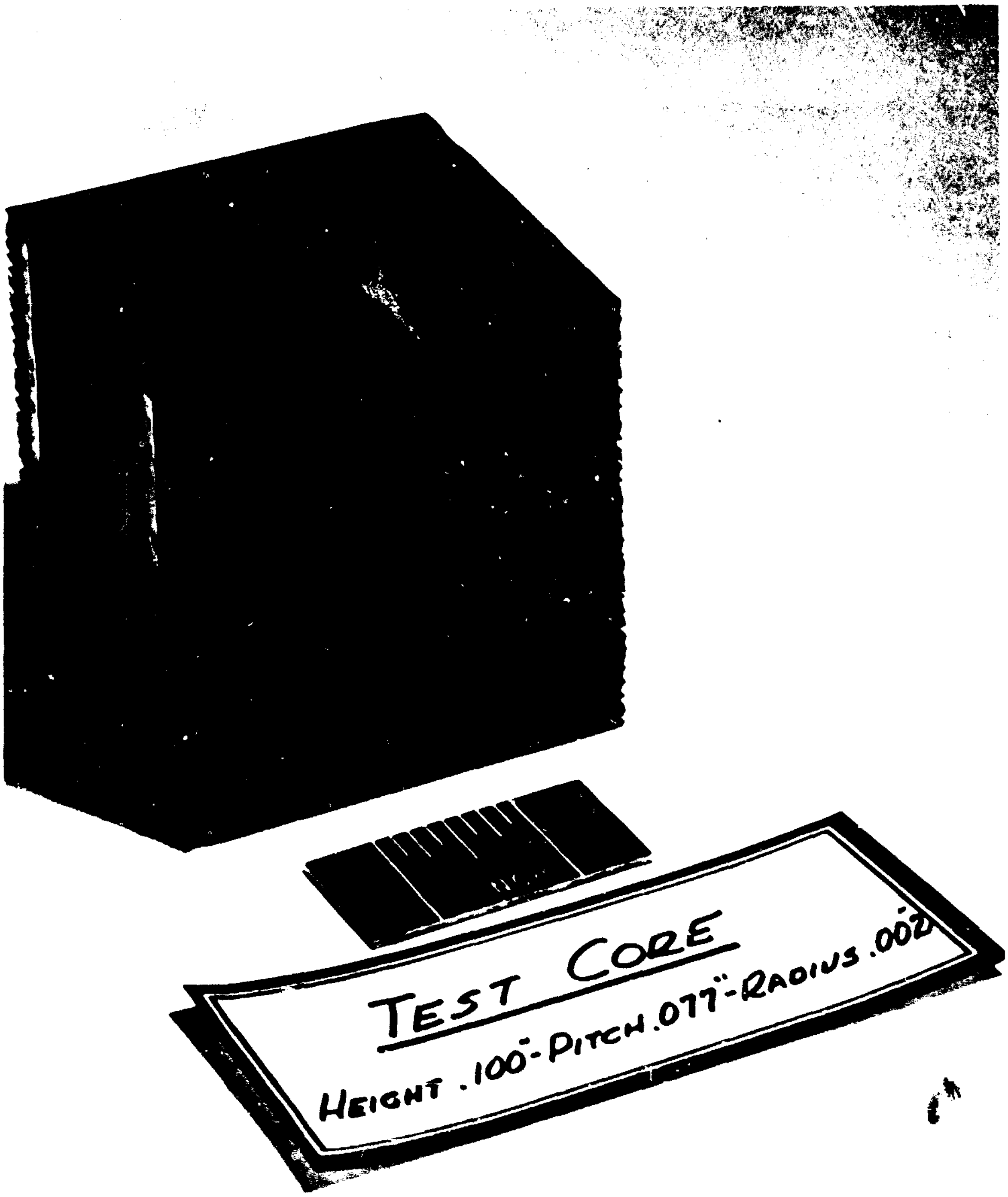


FIGURE 11 - TEST CORE WITH MINIMUM NODE RADIUS - UNBONDED

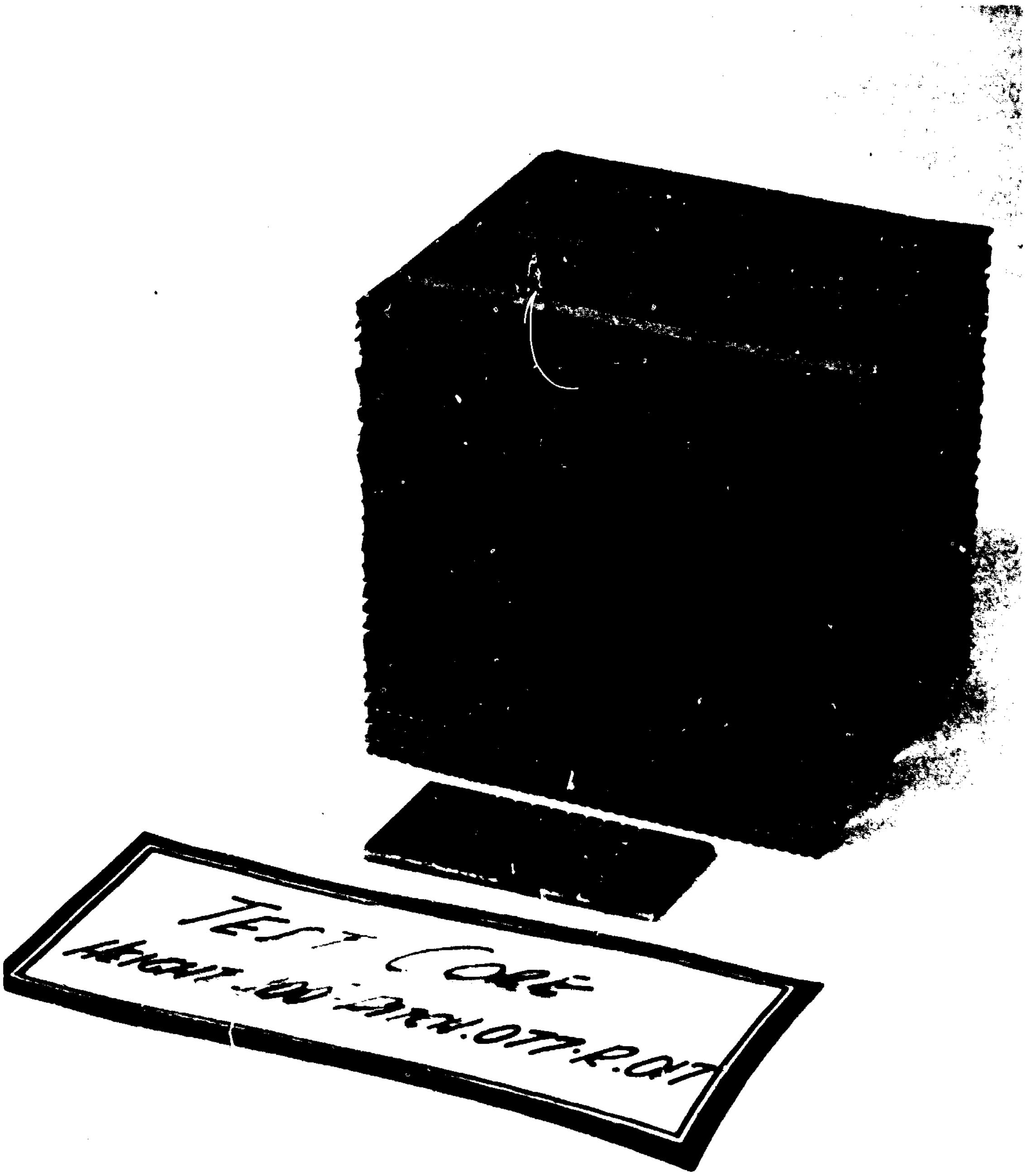


FIGURE 12 - TEST CORE WITH MAXIMUM NODE RADIUS - UNBONDED

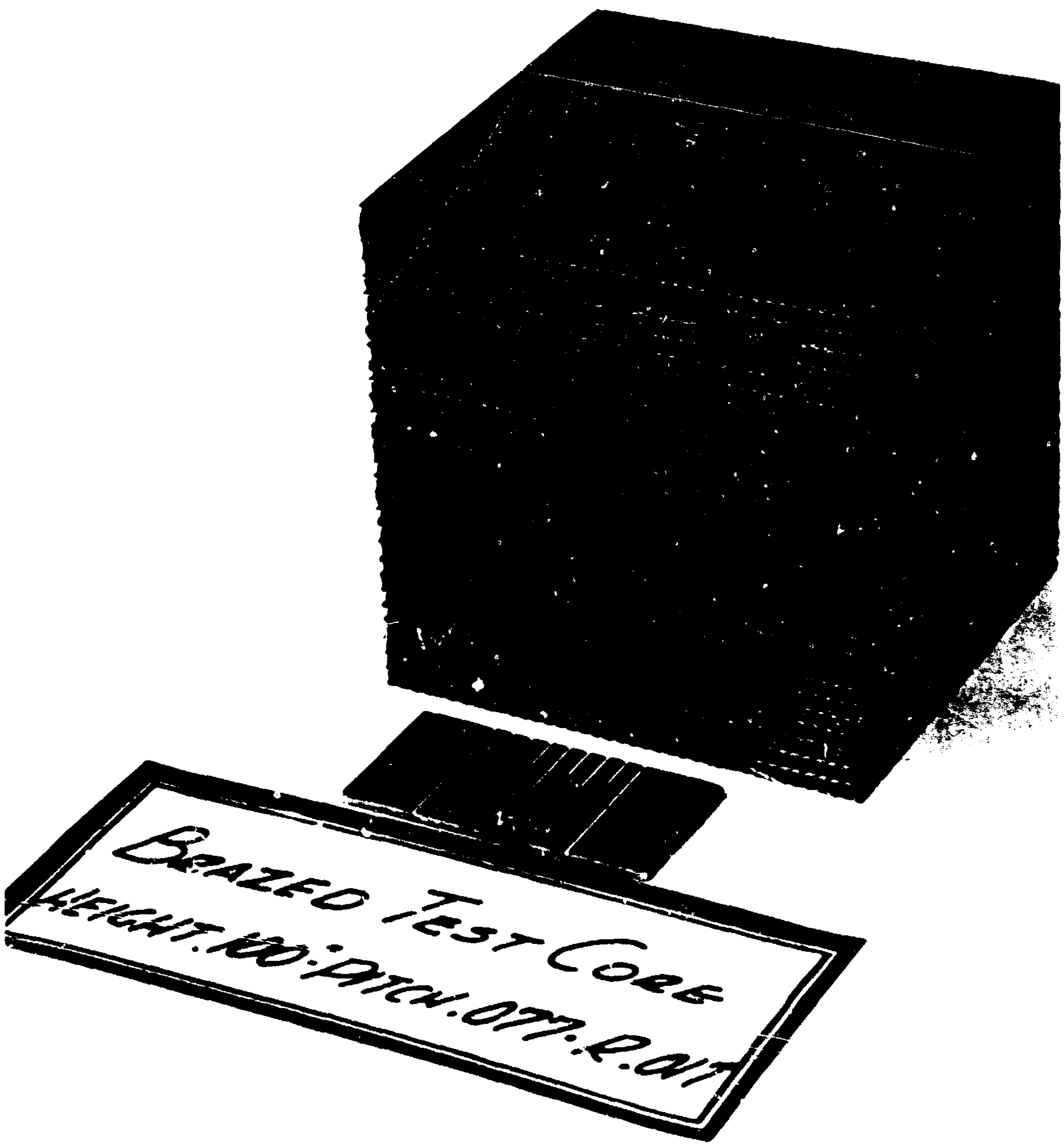


FIGURE 13 - TEST CORE WITH MAXIMUM NODE RADIUS - BRAZED

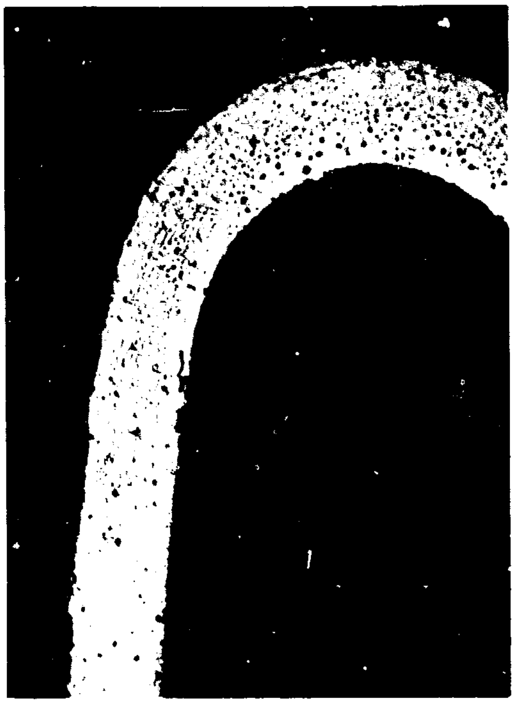


FIGURE 14 - FORMED CORRUGATION
Mat'l 347 - 125 x
Left Side Location
No Stressed Area Apparent

FIGURE 15 - FORMED CORRUGATION
Mat'l 347 - 125 x
Center Location
No Stressed Area Apparent

FIGURE 16 - FORMED CORRUGATION
Mat'l 347 - 125 x
Right Side Location
No Stressed Area Apparent

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13. ABSTRACT

During this report period, 16 parent material-braze alloy combinations have been exposed to testing in the corrosion test rig. Results of this preliminary evaluation are discussed in terms of microstructural attack. Three core modules, fabricated with various passage shapes, are described and projected testing is outlined.

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